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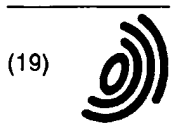
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(54) Method of using copper based electrodes to spot-weld aluminium

Verfahren zur Verwendung von Kupfer-Basis-Elektroden für das Punktschweißen von Aluminium

Procédé d'utilisation d'électrode à base de cuivre pour le soudage par point de l'aluminium

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 - MATSUMOTO J ET AL: "SPOT WELDING OF ALUMINIUM ALLOY-ELECTRODE LIFE FOR VARIOUS ELECTRODES"**

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EP 0 806 263 B1

Description

[0001] This invention relates to the technology of spot-welding metallic pieces and more particularly to spot-welding of aluminium with increased electrical effectiveness and electrode durability.

[0002] Copper electrodes have been used for some time in the spot-welding industry because of their excellent thermal and electrical conductivity and because copper tends to provide the best specific resistance for the welding electrode due to thermal gradients established in the electrode; copper also provides the best contact resistance for the welding electrode because it retains its rigidity and hardness with a high degree of success.

[0003] However, copper electrodes deteriorate rapidly when used to perform mid-frequency DC spot-welding of aluminium sheet material. This is due mainly to a low melting point eutectic alloy that forms at the interface between the electrode and the sheet material. The formation of the eutectic results in rapid erosion of the copper electrode, and presents problems associated with non-uniform and porous nugget formation and nugget shape. (nugget being the melted material that forms the weld joint).

[0004] It is known how to dispersion harden copper electrodes for spot-welding zinc-galvanised steel sheet to avoid brittleness at high temperature use (see U.S. Patent 4,818,283). This dispersion hardening is carried out by dissolving molybdenum in copper above the copper melting point, using a superheat (such as 200-1000°C), followed by rapid cooling of about 10⁴°C per second. Unfortunately, such known dispersion hardening technique fails to recognise or perceive that a certain class of alloying ingredients will suppress the formation of eutectics of aluminium and copper. There is no appreciation that molybdenum, as a representative of such class, would be of service in extending the life of copper electrodes when used to spot-weld aluminium.

[0005] German Patent-A-1565949 describes an electrode for use in the resistance spot welding of aluminium sheet comprising a pseudoalloy of electrolytic copper and 30 to 60% molybdenum, the alloy having been produced by the sintering - metallurgical method. A powder consisting of a mixture of copper and molybdenum is pressed at 4 Mp/cm² and is then sintered in a hydrogen atmosphere for 2 hours at 1000°C. The proportion of molybdenum in the alloy is very much higher than contemplated in the invention to be described. Furthermore the method of producing the copper/ molybdenum electrode is quite different to the method used in the invention.

[0006] It is an object of this invention to reform the composition of copper electrodes to suppress or retard the formation of low melting point eutectics with aluminium by employing alloying ingredients that retard such formation and at the same time remain in solid solution

even at room temperature.

[0007] The invention herein meets such object by a method according to claim 1 for spot-welding aluminium workpieces with copper electrodes that comprises the steps of: (a) super heating copper and one or more elements X that normally have little or no solubility in copper at room temperature, such super heating being a temperature at which X is soluble in copper, X being selected from the group of Mo, Ta, V, and W, X being present in an amount of 4-15% by weight of the copper; (b) rapidly cooling the solution to room temperature to retain such elements as a very small dispersoid in copper; © either concurrently or subsequent to step (b), forming the solution as an electrode shape; and (d) passing current through the electrode shape to effect spot-welding of the aluminium workpieces.

[0008] Super heating and rapid cooling may be carried out by atomising a melt of Cu and X with a pressurised gas that directs the spray onto a target for further cooling and eventual working or shaping. The super heating and rapid heating may also be carried out by concurrently melting powders of Cu and X through use of a thermal spray gun or a laser beam. Either of these modes may be used to create a solid electrode comprised entirely of the alloy or used to create a clad layer or clad tip on a previously shaped copper electrode with X being present only in such layer or tip.

[0009] Alternatively, a solution of X in the copper may be achieved by compacting a mixture of nano-sized particles of X and Cu under sufficient pressure to achieve virtual solution of X in Cu even at room temperature resulting from the intimacy of the particles at their interfaces.

[0010] The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 and 1A are respectively phase diagrams of an alloy of Cu and Mo, and an alloy of Al and each Mo, diagram indicating monotectics of the alloy;

Figure 2 is a schematic illustration of one process for carrying out super heating and rapid cooling of this invention utilising atomisation of a melt of copper and X, X being an element selected from W, V, Ta and Mo;

Figure 3 is a highly enlarged schematic illustration of the structure of one particle formed by the process of Fig. 2;

Figure 4 is an elevational cross-sectional view of a typical electrode that can be formed and shaped by the process of Fig. 2;

Figure 5 is a schematic illustration of an alternative process for carrying out this invention employing concurrent melting of copper and X powders by use of a thermal spray gun;

Figure 6 is a schematic illustration of ion implantation of X alloying material into the surface region of a copper electrode;

Figure 7 is a schematic illustration of yet another alternative process of carrying out super heating and rapid cooling of this invention employing concurrent melting of powders of copper and X utilising a laser beam;

Figure 8 is a schematic elevational view of an electrode which has been clad by the use of the process of Fig. 7; and

Figure 9 is a sectional elevational view of an electrode that has been clad by the process of Fig. 7 but limited to the formation of a cap or tip for the electrode.

[0011] Copper electrode deterioration in the spot-welding of aluminium can be suppressed or eliminated by use of a unique family of alloying ingredients that, when deployed at the electrode interface, suppresses the formation of eutectic alloys between the copper electrode and the aluminium sheet being welded. The family of ingredients, although not usually stable in solution at room temperature in copper, are carefully processed so that total solution of such ingredients in copper will continue at lower temperatures, even to room temperature and below.

[0012] To this end, the electrode interface is fabricated with alloying ingredients X selected from the group consisting of tungsten, vanadium, tantalum, molybdenum. This group is characterised by (a) an inability to form a eutectic with aluminium and, when alloyed with aluminium, drives the liquidus of aluminium much higher, and (b) does not form a eutectic with copper and instead forms a monotectic or peritectic reaction (see the phase diagrams of Fig. 1 and 1A). The alloying ingredients can be added in an amount of 4-15% by weight of the copper to assure that a sufficient amount of the alloying element is present in the copper to exceed the limit of solubility of the element in aluminium when copper is dissolved in aluminium during melting as occurs during spot welding.

[0013] As shown in Fig. 2, a process that will elevate the melting temperature of any liquid that may begin to form at the electrode interface during spot-welding comprises firstly atomising a super heated melt 10 of copper and X (X being present in amount of 4-15% by weight of the copper). Atomisation is carried out by use of a high pressure gas 11 that comminutes the melt into particles 12 of a size of about 10-300 microns. The super-heating is preferably in the range of 538-815°C (1000-1500° F). above the melting temperature of pure copper. Although X is normally not soluble in copper at room temperature, rapid cooling at a rate of 10³⁰ F./minute will trap X in the copper matrix as a well distribute it as a very small disperoid. The collected particles 12 may then be compacted or forged by a machine 13 to form an electrode shape 14 as shown in Fig. 4. This subsequent cold working will produce a wrought copper-X alloy with X remaining trapped in solution in a very finely dispersed form (.5 microns or less). As shown in Fig. 3,

the atomised particles will be a mixture of dispersed X elements 15 within a matrix 16 of copper. The rapid cooling produces particles having a size of about 50 micrometers, with the a melting temperature of each particle being about 1800°C.

[0014] Alternatively, the spray from the atomisation process may be directed onto a substrate and immediately form a coalesced bulk product that is close to the net shape of an electrode, thus requiring little reworking.

[0015] Instead of atomisation, separate powder supplies of copper (20) and X (21) may be milled to nano scale particles (10-30 microns) and blended together in a proportion to accept 4-15% by weight of X (see process in Fig. 5). The homogeneously alloyed particles 22 are then compacted under sufficient force and heat by device 23 to initiate the formation of a solid that has an amorphous microstructure with virtual solid solution of X in copper. Such formation of the amorphous microstructure may be accompanied by heat at a temperature of about 500° F. As a result of the process of Fig. 5, X will be in the particle boundaries of the copper, consistent with being an extremely small disperoid of X in copper (.5 microns spacing or less) and thereby will prevent copper from being preferentially dissolved during the spot-welding operation. Compaction of such nano scale particles into a forged electrode shape, as shown in Fig. 5, will provide certain advantages, namely high strength and ductility combined with the necessary dispersion of the alloying element in the copper.

[0016] As shown in Fig. 6, the extended solubility of X in copper at room temperature may also be achieved by ion implantation. A material 30, constituting X, is irradiated to form an ion vapour 31 that migrates to a copper target 32, such as a reformed copper electrode; the ions 31 bombard the surface 33 of such electrode to create a surface region with X in solid solution. Cladding may also be obtained, as shown in Fig. 7, by injecting copper and X powders (35, 36) into a laser beam 37 where the powders will be melted and X dissolved into the copper. When the melted particles 38, from this laser beam intersection, are deposited on a substrate 39, such as a previously formed copper electrode, a very high cooling rate results and large extensions of solid solubility will occur in such a system. This, of course, results in a surface treated electrode that will retain very high electrical conductivity in the core of the electrode while avoiding the added expense of fabricating the entire solid mass of the electrode with anti-eutectic forming material that may retard conductivity somewhat. The resulting clad electrode, formed either by ion implantation or by concurrent melting and spraying of feed powders, will have an appearance as that shown in Fig. 8.

[0017] Not only is the production of copper-X alloys expensive, the addition of the alloying element lowers electrical conductivity, a principal characteristic of the electrode. An electrode with a uniform CuX composition will therefore be expensive and conduct less effectively than a conventional electrode; this is offset by the ability

of the electrode to be long-lived. Cladding, however, produces a Cu-X layer 40 (see Fig. 8) on a conventional copper electrode that not only will have a longer life but also reduces the need for a costly CuX alloy.

[0018] A variation of this cladding concept would be the formations of a compound electrode 42 (see Fig. 9) by brazing a cap 43 of a copper-X alloy onto the previously formed solid copper electrode 44. Instead of making the whole electrode out of the more expensive Cu-X alloy, a thin cap of the Cu-X material is brazed onto the copper electrode using high conductivity braze material, such as silver, thus lowering the cost of the electrode and extending its life.

Claims

1. A method of spot-welding aluminium workpieces with a copper electrode, comprising:

(a) dissolving copper and one or more alloying elements X, that normally has little or no solubility in copper at room temperature, said copper and X being super heated to an elevated temperature at which X is soluble in copper, X being selected from the group of tungsten, vanadium, tantalum and molybdenum such group exhibiting (i) an inability to form a eutectic with aluminium and, when alloyed with aluminium, driving the liquidus of aluminium much higher, and (ii) not forming a eutectic with copper and instead forms a monotectic or peritectic reaction, X being present in said copper in an amount of 4-15% by weight of the copper;
 (b) rapidly cooling the solution to obtain a very small dispersoid of X in copper;
 (c) either concurrently with or subsequent to step (b) forming said solution as an electrode shape; and
 (d) passing current through said electrode shape to effect spot-welding of said aluminium workpieces when pressed thereagainst.

2. A method as claimed in claim 1, in which said dissolving and rapid cooling is carried out by atomising a melt of copper and X by use of a high pressure gas directing the atomised spray onto a target for further cooling and/or working or shaping to form the electrode.
3. A method as claimed in claim 1, in which said dissolving and rapid cooling is carried out by concurrently melting powders of both copper and X by use of a thermal spray gun or a laser beam.
4. A method as claimed in claim 1, in which said dissolving and rapid cooling is carried out to provide a clad layer or tip on a previously formed solid copper

electrode as the target.

5. A method as claimed in claim 1 in which said dissolving and rapid cooling is carried out by ion evaporation of the element X which ions migrate to a copper electrode target, said ions implanting into the outer surface region of said copper electrode target to form a surface treated copper electrode having X in solid solution in said surface region.
6. A method as claimed in claim 1, in which in step (b) X is present in the copper as an extremely small dispersoid having a spacing therebetween of .5 microns or less.
7. A method as claimed in claim 1, in which copper and the element X are dissolved to form a material that coats only the tip of a performed copper electrode thereby constituting a thin cap at the working end of the electrode.

Patentansprüche

1. Verfahren zur Punktschweißung von Aluminium-Werkstücken mittels einer Kupferelektrode, folgendes beinhaltend:

(a) Lösen von Kupfer und einem oder mehreren Legierungselementen X, das/die normalerweise bei Raumtemperatur keinerlei Löslichkeit in Kupfer zeigt/zeigen, wobei besagtes Kupfer und X bis auf eine erhöhte Temperatur überhitzt werden, bei welcher X in Kupfer löslich ist, wobei X aus einer Gruppe ausgewählt wird, die Wolfram, Vanadium, Tantal und Molybdän beinhaltet, welche Gruppe (i) eine Unfähigkeit zeigt, mit Aluminium ein Eutektikum zu bilden, wenn sie mit Aluminium legiert wird, so daß die Liquiduslinie von Aluminium deutlich höher getrieben wird, und (ii) kein Eutektikum mit Kupfer bildet, sondern statt dessen eine monotektische bzw. eine peritektische Reaktion bildet, wobei X in besagtem Kupfer zu einem Anteil von 4-15 Gew.-% des Kupfers vorliegt;
 (b) rasches Abkühlen der Lösung zur Erzielung eines sehr feinen Dispersoids von X in Kupfer;
 (c) entweder gleichzeitig mit, oder im Anschluß an Schritt (b), Gestalten der besagten Lösung in Elektrodenform; und
 (d) Leiten von Strom durch besagte Elektrodenform zwecks Durchführung der Punktschweißung besagter Aluminium-Werkstücke, wenn sie dagegen gedrückt werden.

2. Verfahren nach Anspruch 1, in welchem besagtes Lösen und schnelles Abkühlen durch Atomisieren einer Schmelze von Kupfer und X unter Verwen-

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 7. Pro- cedé selon la revendication 1, dans lequel le cuivre et l'élément X sont dissous afin de former un matériau qui ne revêt que la pointe d'une électrode de cuivre préformée, constituant ainsi une calotte mince au niveau de l'extrémité active de l'électrode.

3. Verfahren nach Anspruch 1, in welchem besagtes Lösen und schnelles Abkühlen durch gleichzeitiges Schmelzen von sowohl Kupfer als auch X in Pulverform unter Einsatz einer thermischen Spritzpistole oder eines Laserstrahls erfolgt.

4. Verfahren nach Anspruch 1, in welchem besagtes Lösen und schnelles Abkühlen so ausgeführt wird, daß eine Plattierungsschicht oder -Spitze auf eine zuvor geformte volle Kupferelektrode als Target aufgebracht wird.

5. Verfahren nach Anspruch 1, in welchem besagtes Lösen und schnelles Abkühlen durch Ionenverdampfung des Elementes X erfolgt, dessen Ionen in das Kupferelektroden-Target wandern, wobei sich besagte Ionen in den äußeren Oberflächenbereich des besagten Kupferelektroden-Targets implantieren, so daß eine oberflächenbehandelte Kupferelektrode mit X in fester Lösung in besagtem Oberflächenbereich gebildet wird.

6. Verfahren nach Anspruch 1, in welchem in Schritt (b) X als extrem feines Dispersoid im Kupfer vorliegt, mit Abständen von 0,5 Mikrometern und weniger.

7. Verfahren nach Anspruch 1, in welchem Kupfer und das Element X gelöst werden, so daß sie ein Material bilden, das nur die Spitze einer vorgeformten Kupferelektrode beschichtet, um so eine dünne Kappe am Arbeitsende der Elektrode zu bilden.

Revendications

1. Procédé de soudage par points de pièces d'ouvrage en aluminium avec une électrode de cuivre, comprenant :

(a) la dissolution du cuivre et d'un ou plusieurs éléments d'alliage X, qui normalement présentent peu voire aucune solubilité dans le cuivre à la température ambiante, ledit cuivre et ledit X étant surchauffés à une température élevée à laquelle X est soluble dans le cuivre, X étant choisi à partir du groupe constitué du tungstène, du vanadium, du tantale et du molybdène, un tel groupe (i) présentant une incapacité à former un eutectique avec l'aluminium et, lorsqu'il est allié à l'aluminium, entraînant le liquidus de l'aluminium beaucoup plus haut, et (ii) ne formant pas un eutectique avec le cuivre

mais réalise plutôt une réaction monotectique ou péritectique, X étant présent dans ledit cuivre dans une proportion de 4 à 15% en poids du cuivre,

(b) le refroidissement rapide de la solution afin d'obtenir un très petit dispersoïde de X dans le cuivre,

(c) la formation soit simultanément à l'étape (b) soit ultérieurement à celle-ci de ladite solution en forme d'électrode, et

(d) le passage d'un courant à travers ladite forme d'électrode afin d'effectuer une soudure par points desdites pièces d'ouvrage en aluminium lorsqu'elles sont pressées contre celle-ci.

2. Procédé selon la revendication 1, dans lequel lesdits dissolution et refroidissement rapides sont exécutés par projection à chaud d'une masse fondue de cuivre et d'élément X par utilisation d'un gaz à haute pression orientant le produit projeté à chaud sur une cible pour ensuite un refroidissement et/ou un travail ou une mise en forme en vue de réaliser l'électrode.

3. Procédé selon la revendication 1, dans lequel lesdits dissolution et refroidissement rapides sont exécutés en faisant fondre simultanément des poudres à la fois de cuivre et d'élément X en utilisant un pistolet pour projection à chaud ou un faisceau laser.

4. Procédé selon la revendication 1, dans lequel lesdits dissolution et refroidissement rapides sont exécutés afin de réaliser une couche ou une extrémité de plaquage sur une électrode de cuivre solide préalablement formée en tant que cible.

5. Procédé selon la revendication 1, dans lequel lesdits dissolution et refroidissement rapides sont exécutés par vaporisation d'ions de l'élément X lesquels ions migrent vers une cible d'électrode de cuivre, lesdits ions venant s'implanter dans la région de surface extérieure de ladite cible d'électrode de cuivre pour former une électrode de cuivre traitée en surface ayant l'élément X en solution solide dans ladite région de surface.

6. Procédé selon la revendication 1, dans lequel au cours de l'étape (b) l'élément X est présent dans le cuivre sous forme d'éléments d'un dispersoïde extrêmement petits présentant un espacement entre eux de 0,5 micromètre ou moins.

7. Procédé selon la revendication 1, dans lequel le cuivre et l'élément X sont dissous afin de former un matériau qui ne revêt que la pointe d'une électrode de cuivre préformée, constituant ainsi une calotte mince au niveau de l'extrémité active de l'électrode.

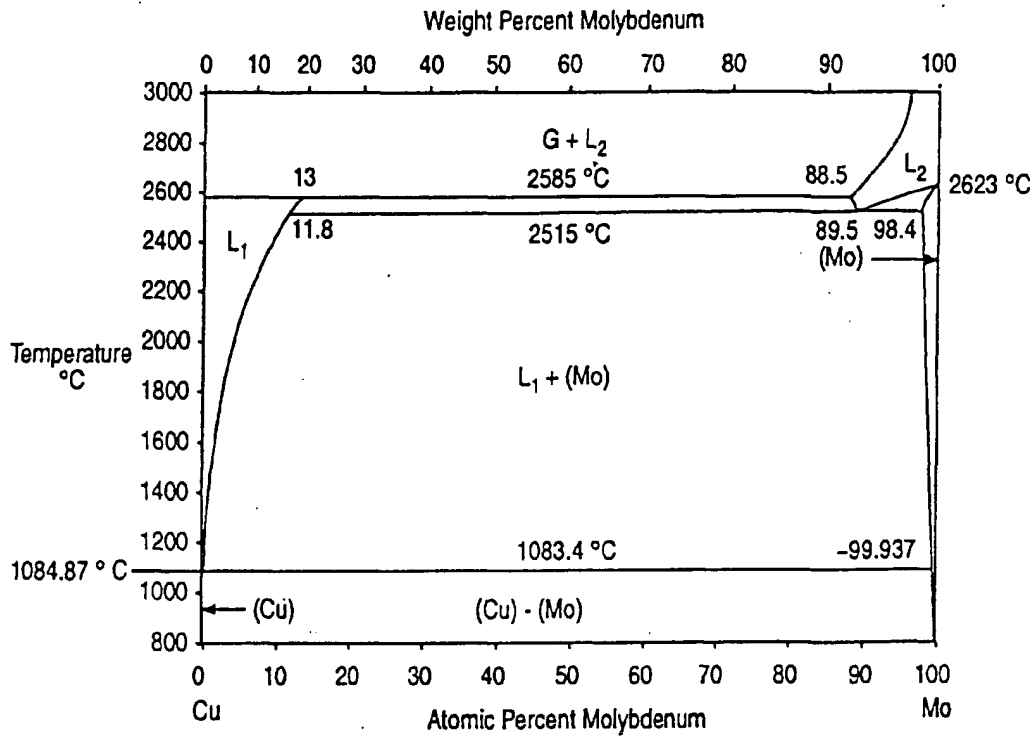


FIG.1

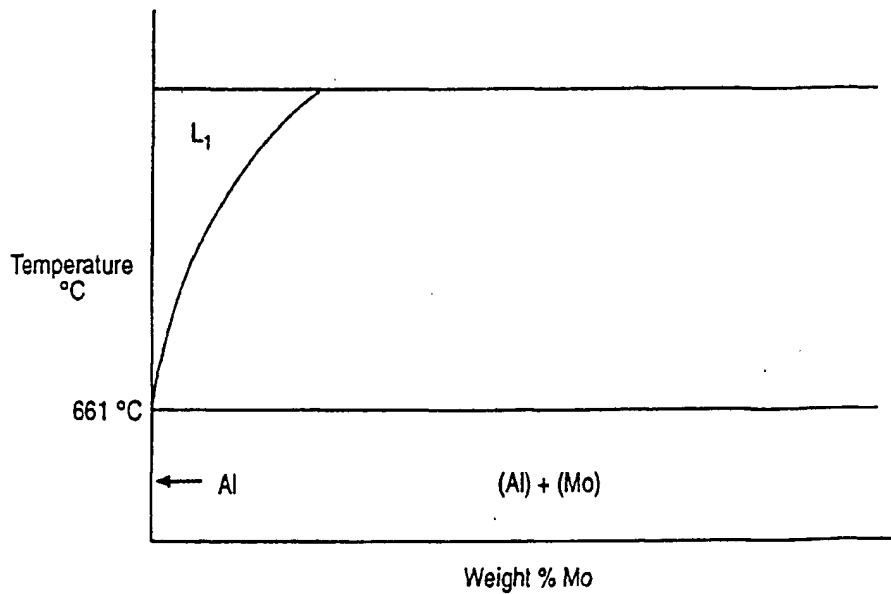


FIG.1A

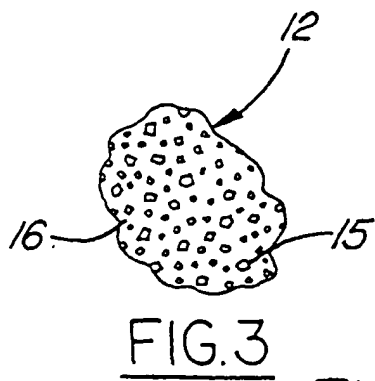
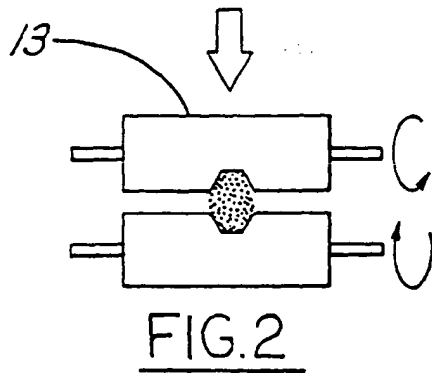
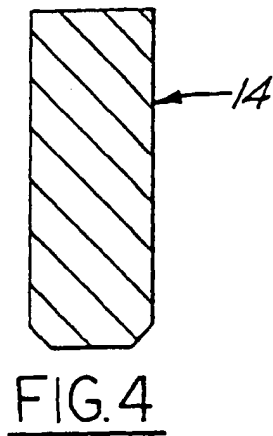
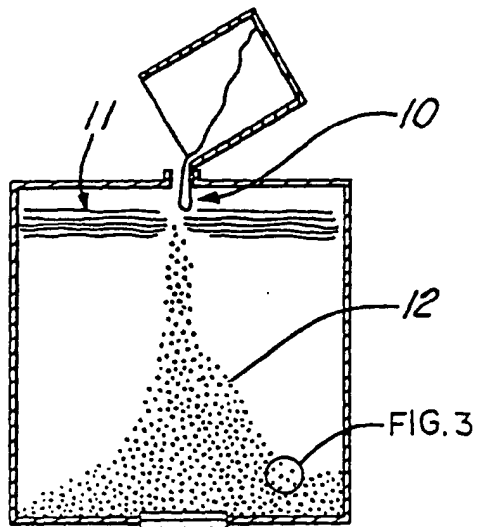
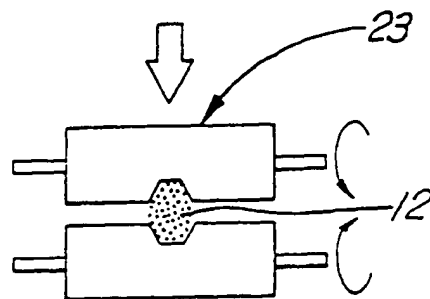
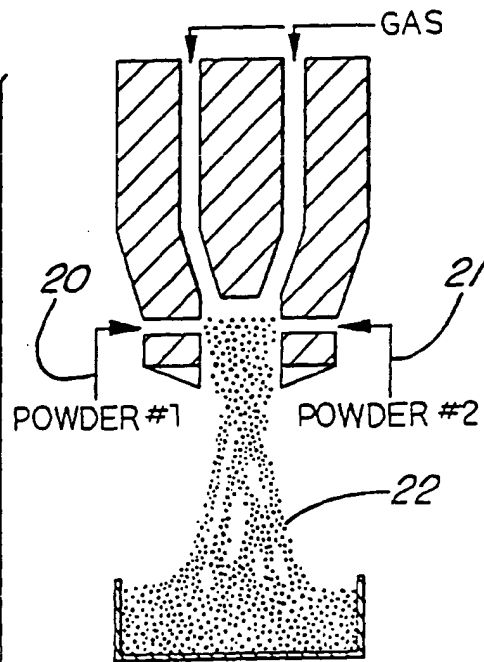


FIG. 5



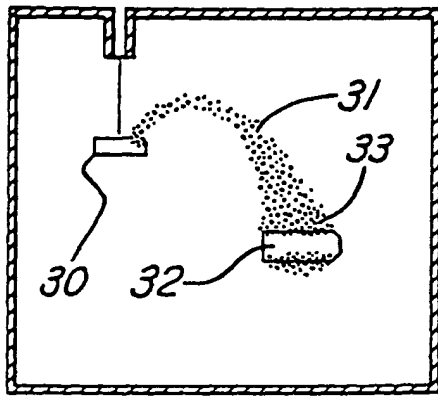


FIG. 6

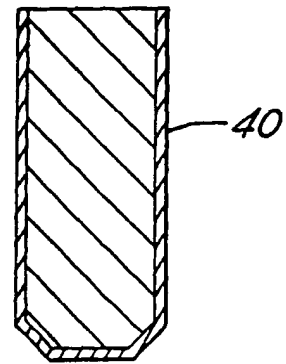


FIG. 8

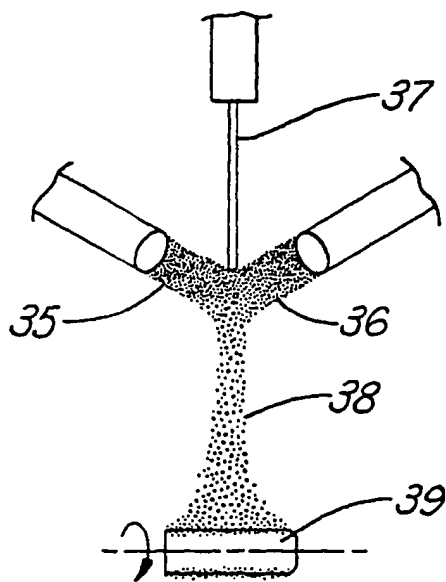


FIG. 7

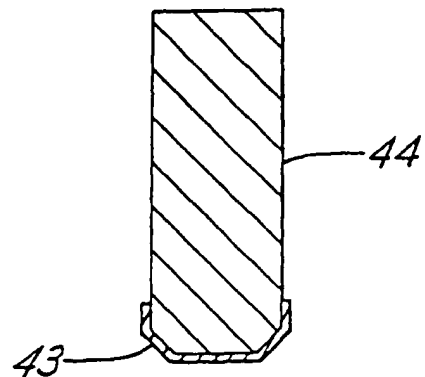


FIG. 9